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Green infrastructure planning: Unveiling meaningful spaces through Foursquare users' preferences

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ABSTRACT

The design of efficient Green Infrastructure —GI— systems is a key issue to achieve sustainable development city planning goals in the twenty-first century. This study's main contribution is the identification of potential GI elements to better align the environmental, social and economic perspectives in the GI design by including information about the use, activities, preferences and presence of people. To achieve this, user generated content from Location Based Social Network —LBSN— Foursquare is used as a complementary data source. This involved the construction of an interdisciplinary correlation framework, between the Landscape Ecology principles and the GI elements, that included the classification of Foursquare data into grouping types. The classification considered the potential role of Foursquare *venues* in the GI network. Valencia City in Spain served as an illustrative case study to test the validity of the proposed method. The results suggest that Foursquare can provide a valuable insight on user perceptions of potential GI elements. Moreover, the findings indicate that user generated content from LBSNs like Foursquare can serve as a complementary tool for analysing the dynamics of urban outdoor spaces to assess GI network, thereby facilitating more effective urban planning and contributing to the social sustainability of the city.

1. Introduction

In the European context, landscape ecology principles, which are mainly focused on the preservation of species and habitats (Jongman and Pungetti, 2004), have been integrated into landscape planning to deal with urban planning challenges (Tzoulas et al., 2007). Moreover, landscape ecology principles have also been adopted and adapted, specifically for the design of a Green Infrastructure —henceforth, GI—, a multiscale approach that considers the identification of patterns and dynamics (Ahern, 2007;270). This way, the consideration of cities as integrated socio-ecological systems has provided the basis for defining GI strategies (Artmann et al., 2017; Bastian, 2002), which has become a key issue in the urban planning of twenty-first century cities (Ahern, 2007; Artmann et al., 2019; Atik et al., 2015, 2017; Benedict et al., 2006; Davies and Lafortezza, 2017).

The importance of implementing GI, in both urban and rural areas, gained momentum from 2009 when the European Commission presented the report "Adapting to climate change: towards a European framework for action". Accordingly, GI has been well considered for its valuable capacity to provide "essential resources for social and economic purposes under extreme climatic conditions". One of the principal ideas exposed was to "work with nature's capacity to control impact in urban and rural areas" (European Commission (EC), 2009; 5)

Moreover, the GI concept has been integrated into strategic planning tools adopted by several EU institutions to guide "the policies of territorial cohesion, nature conservation and urban sustainability" (Feria Toribio and Santiago Ramos, 2017; 540). Also, different actions and programs have been implemented such as the European Strategy on GI —Enhancing Europe's Natural Capital (European Commission, 2013a) —. This European strategy involves a yearly average investment of 915 million €, set up during the 2014–2020 programming period. However, GI green zones which include green urban and peri-urban

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areas are underfunded as the maximum allocated budget was only 9% of the total (European Commission (EC), 2016).

Specifically, in Spain, the European Landscape Convention agreement officially entered into force in 2008; but the "National GI and Ecological Connectivity and Restoration strategy" is still pending approval in order to meet European Commission GI objectives (Vera-Rebollo et al., 2019). Currently, the GI concept is being progressively introduced into the regional and local planning strategies under different names yet pursuing common sustainable goals (Feria Toribio and Santiago Ramos, 2017). Indeed, the GI network must be adapted to both: the consolidated urban tissues lacking of green connectivity; and, the current city planning that has not integrated an ecological network from its inception. These facts have slowed down the GI implementation in the Spanish context.

The integration of the GI in cities is a core long-term strategy for urban planners to meet broader goals in relation to: environmental balance (Cortinovis and Geneletti, 2018; Li et al., 2017; Schäffler and Swilling, 2013); sustainability (Artmann et al., 2019; Biazen Molla, 2015; Breuste et al., 2015; Li et al., 2017; Mell, 2009); and, healthy urban contexts (Cortinovis and Geneletti, 2018; Gupta et al., 2016; Kabisch et al., 2016; Sonter et al., 2016). Specifically, the connection of the urban environment with natural areas enhances community well-being and the performance of natural dynamics (Kabisch et al., 2016; Sonter et al., 2016; Žlender and Ward Thompson, 2017).

This study adopts a generally accepted and broad definition of GI as "the ecological framework for environmental, social and economic health" (Benedict et al., 2006, p.1), which covers multi-disciplinary and multi-scalar aspects (Nogue and Pere, 2010). Moreover, GI is considered "a strategically planned and delivered network comprising the broadest range of high-quality green spaces and other environmental features" (Wood, 2009, p. 7).

According to the GREEN SURGE project report of 2014 (Davies et al., 2015), only seven of the 32 European studied city plans mentioned the term GI and, from these, only in four cases —Edinburgh, Liverpool, Bristol and Barcelona — was it possible to find references to connections between GI and spatial planning (Lai et al., 2019). However, even though the project incorporated participatory planning through the Urban Learning Labs and using "Geo-Wiki's" to receive feedback on spatial data from individuals, none of the four cases offered specific information about whether user habits or preferences had been considered for GI planning design. Furthermore, it is worthy to highlight that these consultations were conducted in specific events, thus for a very specific target sample.

Hence, this research aims to contribute to fill this gap by designing an interdisciplinary correlation framework which establishes links between Landscape Ecology components, GI elements, and user preferences and perceptions of city spaces through the analysis and interpretation of geolocated Location Based Social Networks —LBSN— data. That is, location-tagged data voluntarily generated by users themselves. Therefore, the approach presented is likely to be more representative because it incorporates the digital traces that reveal user preferences for green public spaces, urban facilities and most frequented places.

Although the potential of LBSN data for studying a range of issues in urban environments has been widely recognized in the literature (Anselin and Williams, 2015; Arribas-Bel, 2014; Heikinheimo et al., 2017; Roick and Heuser, 2013; Shelton et al., 2015), there is still an unexplored area in the application of location-based user-generated sources for GI planning and design, as described in the literature review section. This study addresses the extent to which working with these sources could potentially contribute to better informing urban planning policies for the design of GI (He et al., 2018; Kourtit and Nijkamp, 2018; Sonter et al., 2016).

Thus, the main objective of this study is to design a method for identifying meaningful urban spaces that should be considered as potential elements of the GI network in a given city, by using geolocated data from the social network Foursquare. Foursquare classifies urban activities —*venues*— into ten main categories, and, into different levels of subcategories that provide a more accurate description of the different types of places. In this study, the use of Foursquare first subcategory level introduces the necessary detail to both, correlate these places to specific GI elements and depict nuances related to *venue* types.

The present research provides two novelties. The first lies in the provision of an interdisciplinary correlation framework which links landscape ecology components, GI elements, and Foursquare subcategories; and, the second, is related to the use of user generated content to unveil green outdoor spaces with a relevant role for users, including both locals and visitors. Moreover, the study explores the potential of Foursquare data as a complementary source of information for urban GI planning processes. To validate and discuss the results, the method designed is applied to the city of Valencia in Spain as case study. The discussion includes a comparison of the findings to the current city's GI plan to identify the extent to which the elements of the GI network are aligned to social preferences or people presence.

1.1. Literature review

This section builds the path following those research lines which contribute to identify GI elements and characteristics at a multiscale spatial context, including the social dimension. For this latter purpose, the identification of research papers dealing with the use of LBSNs for assessing different city issues is the way of narrowing the existing research gap.

1.1.1. Green infrastructure elements

GI is widely considered in urban and regional planning processes (Davies et al., 2006; Kambites and Owen, 2006; Llausàs and Roe, 2012; Mell, 2009) as it is recognized for its potential to bring together green spaces and natural systems — that should be actively protected, managed or restored — and balancing them with land development and man-made infrastructure planning (Benedict et al., 2006). Among the various definitions, the elements that constitutes the GI include a broad range of overlapping assets — from street trees to green roofs, city parks, vacant and derelict land or play areas, to name a few — (Salata and Yiannakou, 2016). These elements are multi-scale from territorial to local urban scale, and multifaceted, not only the natural elements themselves but also the uses, activities and buildings that are linked to them.

In order to promote a richer and interconnected GI network, the identification of specific elements of the GI at the local scale is relevant in relation to, for example, the distances between green areas (Chen et al., 2018b); their size and characteristics (Giles-Corti et al., 2005; Mell, 2009; Makhzoumi, 2003; Rueda et al., 2007); the accessibility of residents to open air activity spaces (Wüstemann et al., 2017; Žlender and Ward Thompson, 2017); or, the location of surrounding facilities (Akpinar, 2016; Pérez Igualada, 2013; Schipperijn et al., 2013; Tillie and van der Heijden, 2016). Indeed, some of these characteristics have proven to clearly influence the increasing number of visitors to GI, such as the proximity of green areas to densely populated districts (Donahue et al., 2018); or, the accessible location of art installations, cultural spots or sports facilities (Cord et al., 2015; Pérez Igualada, 2016; Schwartz and Hochman, 2014).

GI elements not only refer to physical features but also to facilities, open air activities, and user preferences that contribute to a comprehensive understanding of the GI as a complex network at the urban scale (Narciso, 2018). Precisely, the complexity of the GI network may be the reason why different studies have detected that the implementation of weak solutions that lack connectivity among different elements and facilities within the city compromises the resilience of green areas in the long run (Makhzoumi and Pungetti, 2008; Niță et al., 2018). Additionally, several researchers are assessing the so-called green gentrification as an unanticipated and undesirable side effect of the implementation or renovation of urban green spaces in vulnerable neighbourhoods (Anguelovski et al., 2019; Cole et al., 2017).

1.1.2. LBSNs as a tool for GI planning

Location Based Social Networks —LBSN— data sources are increasingly being used in landscape studies and have proven to be a valid resource for the analysis of issues related to GI management and planning at different scales (Hamstead et al., 2018; Tasse and Hong, 2014, 2017). Moreover, crowd-sourced social media data have been considered a cost-efficient source to rapidly measure parameters and monitor a broad range of issues compared to both traditional field techniques of data collection and the official databases from governmental institutions (Donahue et al., 2018; Dunkel, 2015; Hamstead et al., 2018; Hausmann et al., 2018; Heikinheimo et al., 2017; Sessions et al., 2016).

Specifically, geotagged images from LBSNs have been used to assess several issues, such as: park visitation rates and patterns through Flickr and Instagram (Donahue et al., 2018; Hamstead et al., 2018; Keeler et al., 2015; Sessions et al., 2016; Sonter et al., 2016; S. A. Wood et al., 2013); landscape perception through Flickr (Dunkel, 2015); use, attractiveness and associated recreational activities in urban and non-urban contexts through Instagram and other LBSN apps designed for tracking running activity (Chen et al., 2018b; Heikinheimo et al., 2017); and, the socio-cultural values of landscape through Instagram (Chen et al., 2018a).

Most of the aforementioned studies have provided an analysis of large non-urban green areas, such as national parks, conservation areas, flagship parks, and other natural spaces, that draw in a large number of visitors (Heikinheimo et al., 2017; Sessions et al., 2016; Sonter et al., 2016). In most cases, these studies are sourced from geotagged photographs and only a few use Twitter or other types of geolocated crowd-sourced information (Afzalan and Muller, 2014; Gupta et al., 2016; Luz et al., 2019; Salata and Yiannakou, 2016).

However, at local scale, there is a scarcity of research concerned with urban green areas that use geolocated social media data (Donahue et al., 2018; Hamstead et al., 2018; Schwartz and Hochman, 2014). Some of the few studies available focus on the identification of local points of interest, landmarks, user preferences or attractive areas. These are frequently related to elements of the GI and have been identified by using geotagged images and tweets (Bubalo et al., 2019; Donahue et al., 2018; Ferrari et al., 2011; García-Palomares et al., 2015; Huang et al., 2015; Martí et al., 2019a, 2017; Rai et al., 2018). Therefore, the potential offered by other LBSN data sources has not been fully exploited (Rösler and Liebig, 2013; Shelton et al., 2015) and this study contributes to fill this knowledge gap.

Specifically, this study uses Foursquare data as the social network that enables users to "check-in" a *venue* in order to broadcast their visit and share their opinions about their experience. Indeed, Foursquare, along with other social networks with similar functionalities, have been used by previous studies and have demonstrated their potential for assessing issues related to GI. For instance, public green space accessibility has been analysed through data from Jiepang —one of the largest check-in based LBSNs in China— (Shen et al., 2017) and park visitation has been measured by using data from Sina Weibo —the equivalent of Twitter in China— (Zhang and Zhou, 2018). In these studies, the check-in value is considered an indicator of the number of visitors that have registered their presence in an urban green space, and that is the approach adopted by this paper.

At this point, based on the revised literature, Table 1 presents a specific correlation framework for GI elements at city scale (Benedict et al., 2006) in relation to Landscape Ecology components at territorial scale (Hobbs et al., 2007) and specific social network subcategories for spatial distribution of users' activities and preferences at local level (Agryzkov et al., 2016).

Table 1
Correlation between Landscape Ecology components, Green Infrastructure elements and LBSN data subcategories.

Landscape ecology	Green infrastructure	Check-in based LBSN data
Structure & function P + C	Interconnected GI network	Spatial distribution of user's activities and preferences
Mosaic	GI elements	Categories and Sub-categories
Patches	**Green hub areas**	**Natural elements** green areas
	Activity hotspots	**GI attractor facilities** Hotspots
Corridors	**Linking trails**	**Connectors** public space network

2. Sources

The check-in based LBSN Foursquare was selected as the main source of information for this study as it represents a dynamic up-to-date information source for identifying user preferences and presence. This social network has proven to be effective for the identification of socially relevant urban public spaces (Martí et al., 2017) as the metadata retrieved include, among others, the cummulative number of unique users, visitors and check-ins per registered *venue*. Through these values it is possible to know how many Foursquare users have passed by, visited and stayed or broadcasted their presence in a *venue*, respectively. It is noteworthy to mention that *venues* are not registered automatically in the platform database as in the case of other social networks —i.e. Google Places—, users themselves can register a *venue*. Thus, only those urban spaces that have intentionally been registered are in the platform database. Considering this fact, the assumption is that i) *venues* are already somehow preferred/demanded places over others available in the city; and, ii) the total number of unique users is used as a proxy value for gauging the preferences of people for certain urban spaces over others.

As for Foursquare's raw datasets, they are rather consistent, as *venues* tend to be properly categorized and thus, require less initial dataset wrangling than other place-based social networks (Martí et al., 2019b). Even though users can register and edit a *venue* themselves, this social network has a style guide and *venue* updates which are verified by superusers on a voluntary basis (J. Williams and Chorley, 2017).

Moreover, most data are properly organized into categories and subcategories. Unlike other LBSNs, Foursquare's five-level hierarchy of *venue* categories, with over 700 *venue* types (Foursquare Inc., 2019), provides rich and organized semantic information on registered *venues* (Williams and Chorley, 2017). The *venue* category, subcategory and, if available, subsequent subcategories, indicate the type of place or establishment. The more subcategories a *venue* has, the more specific and richer is the description of the *venue's* use. Indeed, Foursquare's hierarchical organization of *venues* facilitates the dataset filtering and interpretation processes, as determined by the research question.

There are ten main Foursquare categories available: *Arts and Entertainment; Food; Nightlife Spot; College and University, Event, Outdoors & Recreation; Professional & Other Places; Residence; Shop & Service; Travel & Transport* (Foursquare Inc., 2019). For this study, the category *Outdoors and Recreation* is considered the most relevant as it includes most of the Foursquare *venues* that closely relate to the elements and spaces that traditionally comprise the GI. For instance, subcategories such as, *Park, Bike Trail, Botanical Garden* are included within this category. Therefore, exclusively focusing the analysis on *venues* in this category would allow the identification of most urban spaces that are relevant to the user from the GI perspective, whereas the other eight categories would normally include *venues* that users perceived to be associated with other urban activities.

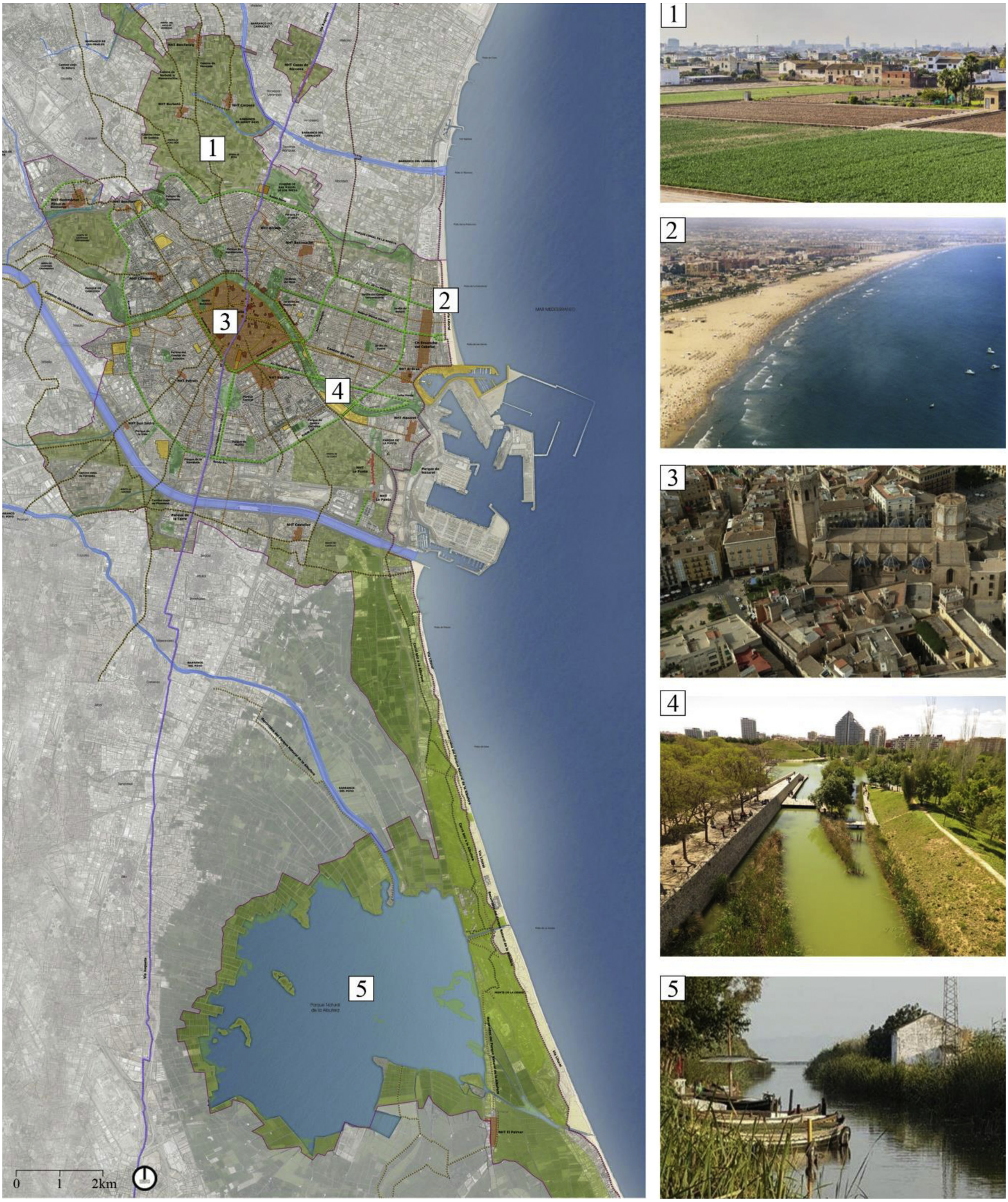

Fig. 1. Valencia City. Main landscape elements linking territorial and urban scale: 1. The millenary agricultural system of the *Huerta*; 2. The Mediterranean shoreline; 3. Valencia old City Centre; 4. The Turia River urban basin, currently transformed into a backbone for main city leisure and cultural facilities; 5. The Albufera of Valencia Natural Park. Source: (Ayuntamiento de Valencia, 2014).

3. Illustrative case study. Valencia, Spain

In Spain, it is the regional legislation on spatial planning that establishes the framework for the development of GI at a regional level, aiming to approach the territory through a multiscale structuring methodology (Cantó López, 2014a). The Valencian Autonomous Community was, in 2004, one of the earliest territories to include the GI network planning concept into its planning legislation with a visionary perspective —Law 4/2004 of spatial planning and landscape protection of the Valencian Autonomous Community, later replaced by the new Law 1/2019 — (Cantó López, 2014b).

As the main city in the central Spanish Mediterranean Arc, with the second highest population after Barcelona, Valencia is highly suitable as an illustrative case study. Valencia has several singular features —illustrated in Fig. 1 — including the following: 1) the city's periphery maintains one of the few remaining examples of the European *Huerta* landscape —Valencia city is surrounded by more than 10,000 ha of historical agricultural Mediterranean *Huerta* — ; 2) the city's location alongside the Mediterranean Sea, which is a highly relevant environmental component; 3) the historic city centre, with an extension of 227 ha, is a heritage protected site where relevant urban assets are located; 4) the Turia River bed which traverses the city centre and was transformed in the 1980s into a 170 ha park, making it a consolidated "green backbone" that impacts both the territorial and urban scale—; and, 5) the proximity of the Albufera natural park, one of the remaining Mediterranean wetlands of reference in Europe —more than 21,000 ha of bird nesting and rice production—. These unique features offer a very favourable spatial context for developing an integrated GI network that interlinks important natural, cultural and heritage elements at territorial scale with urban local spaces anchored in the city's social framework — Fig. 1 — (Giampino, 2018).

Despite having been one of the pioneer Spanish autonomous communities in the introduction of a GI planning strategy, it was not until 2015 that Valencia city's GI plan was implemented (Ayuntamiento de Valencia, 2014) — Fig. 1 —. This is the first municipality in the Valencian Community which developed a GI proposal integrated into the city's urban plan.

4. Research design – method

The overall research design —see Fig. 2— consists of the following steps —described in the corresponding sub-headings—: (i) Foursquare data retrieval and verification; and (ii) the identification of GI elements, classified under category *Outdoors & Recreation,* in two different stages, one related to the selection of Foursquare subcategories by type and social significance —users— and the other considering the character and management of the *venues* as well as their social significance. Moreover, the method is validated (iii) by applying it to an illustrative case study, and the results obtained are compared to the current the GI Plan of the city.

4.1. Data retrieval and verification

Foursquare data sourced from the city of Valencia have been retrieved on 2 March 2018 through Foursquare's API service via a self-developed web application — ("reference removed for blind peer review")—. The dataset information contained cumulative and updated data including variables related to (1) *venue* geolocation —latitude and longitude coordinates—; (2) *venue* name; (3) cumulative number of check-ins per *venue*; (4) cumulative number of users per *venue*; and, (5) a set of *venue* categories that follow a hierarchical structure where each category has a finite number of subcategories (Barlacchi et al., 2017; Foursquare Inc., 2019).

Once retrieved, only those *venues* within the *Outdoors and Recreation* category were included and the rest were discarded. The following step was to verify that *venues* were not over-represented or duplicated in the dataset. The criteria adopted for this purpose was to sum the number of users, merge the subcategories, and select one name to represent that *venue* in the dataset in the case that different *venues* were registered with similar or the same name, or slightly different geolocation coordinates. An example of this process is the case of Playa de la Malvarrosa presented in Table 2.

4.2. Identifying GI elements through Foursquare data

A two-step procedure has been adopted to identify the urban spaces that are relevant to the GI in the city of Valencia by using Foursquare data, as developed in the following sub-sections. Firstly, according to the interdisciplinary correlation framework, the *Outdoors and Recreation* Foursquare subcategories were classified considering their role in the GI network —Table 3—; secondly, further consideration was given to the indoor/outdoor character of *venues* and their type of public/private management. Finally, to ensure an accurate selection of subcategories and *venues* for the configuration of the GI network, the social significance of the selected subcategories and *venues* was assessed through the number of registered users —Table 4—.

4.2.1. Correlation between GI elements and Foursquare subcategories

Finding a correlation between GI elements and Foursquare data subcategories that better interrelates Foursquare user categorization of *venues* to their role within the GI network involved matching the 63 general Foursquare subcategories to the most suitable type of GI element. This procedure has permitted the classification of Foursquare data into grouping types that are related to GI elements, thereby linking landscape planning concepts to LBSN data.

The conceptual link between the GI elements and Foursquare data was grounded in the following: firstly, GI natural elements have been acknowledged in the literature as hubs where the natural component

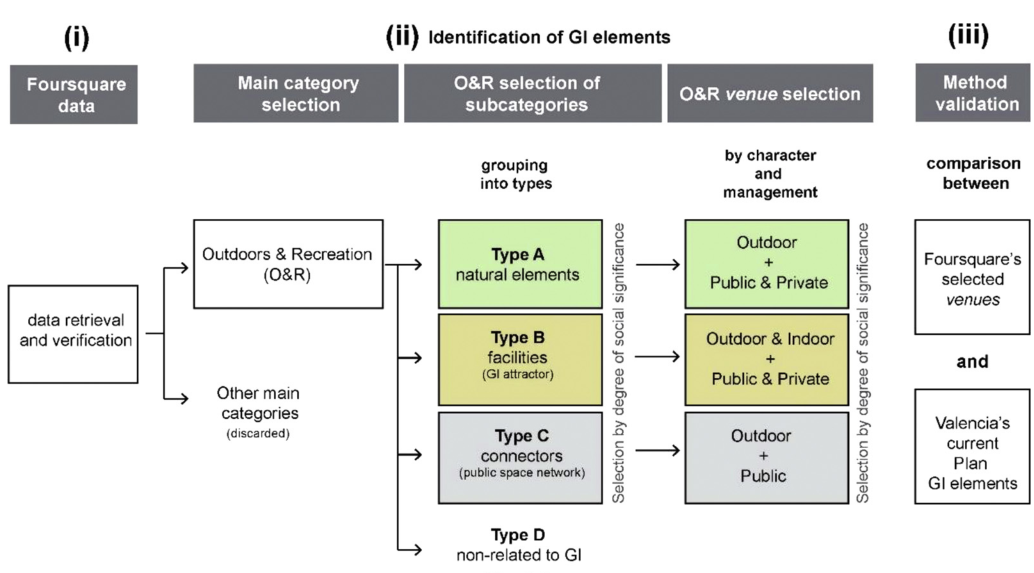

Fig. 2. Research design – Method diagram.

Table 2
Exemplification of data verification process in the case of the over-represented *venue* Playa de la Malvarrosa.

	Venue	Checkins	Users	Main category	Category	Subcategory 1
a	MalvaBeach (Paya de la Malvarrosa)	16,524	8961	Outdoors & Recreation	Outdoors & Recreation	Beach
b	Platja de La Malvarrosa	3	3	Outdoors & Recreation	Outdoors & Recreation	Beach
c	Playa Malvarrosa De Corinto	95	86	Outdoors & Recreation	Outdoors & Recreation	Beach
d	La Malvarrosa	42	32	Outdoors & Recreation	Outdoors & Recreation	Beach
a + b+c + d	**MalvaBeach (Playa de la Malvarrosa)**	**16,664**	9082	**Outdoors & Recreation**	**Outdoors & Recreation**	**Beach**

has a greater presence, and therefore can be considered "green", —parks, gardens, rivers, etc.— (European Commission, 2013b); secondly, GI attractor facilities are those spaces where there are permanent or temporal activities promoting social dynamism in their surrounding area —children's playground, multipurpose sports grounds, dog runs, etc.— (East Ayrshire Council, 2017; The Scottish Government, 2011); and, thirdly, connectors or corridors are the links supporting interconnected green spaces at multi-scale levels —plazas, streets, avenues, bridges, etc.— (Mell, 2009).

Therefore, according to these criteria, the following four groupings were proposed, and the standard Foursquare Outdoors & Recreation subcategories were classified accordingly as shown in Table 3:

- Type A - Subcategories containing *venues* that comprise proper elements of GI, such as parks, gardens, or beaches.
- Type B - Subcategories potentially containing activities related to the use or enjoyment of GI spaces. —i.e. Athletics & Sports, Fountain, Dive Spot, etc.—
- Type C - Subcategories containing elements that could be potentially considered as connectors of the GI. In this grouping, a broad network of public spaces is considered since *plazas*, routes, and trails can frequently work as link-corridors in the GI.
- Type D - Subcategories whose *venues* do not relate to GI elements —for instance, Foursquare sub-category *States & Municipalities*— and *venues* that are unclassified remain in a fourth group and were discarded for the purpose of this study.

The general classification of the original 63 Outdoors and Recreation Foursquare subcategories into the four groupings resulted in: 24 subcategories following Type A; 29 subcategories following Type B; eight subcategories following Type C; and, two subcategories, including the unclassified *venues*, following Type D (Table 3).

Once subcategories were grouped into types, they were ranked by the number of total users to determine their degree of social significance at the GI local scale. Subcategories amounting to less than a set number of users, namely 20, were discarded. The number set should be determined and specified on a case-by-case basis, according to the available data and the population in the city.

Table 3
Relation between GI elements, Foursquare Outdoors & Recreation subcategories, and grouping Types.

Green Infrastructure [GI] — GI elements / Network	**LBSNs data** — Foursquare Category: Outdoors & Recreation — Sub-categories		**Method** grouping TYPES
Green hub areas	**Natural elements** areas	Park, Garden, Botanical Garden, Field, Island, Beach, River, Canal, Hill, Waterfront, Campground, Volcano, Mountain, Cave, Lake, National Park, Bay, Forest, Nature Preserve, Reservoir, Vineyard, State/Provincial Park, Waterfall, Other Great Outdoors	**Type A**
Activity hotspots	**GI attractor facilities** hotspots	Athletics & Sports, Playground, Dog run, Scenic Lookout, Cemetery, Sculpture Garden, Hot Spring, Palace, Indoor play area, Castle, Lighthouse, Fountain, Pool, Ski Area, Recreation Center, Farm, Stables, Bathing Area, Dive Spot, Gun range, Well, Rock Climbing Spot, Summer Camp, Mountain Hut, Fishing Spot, Rafting, Roof Deck, Skydiving Drop Zone, Windmill	**Type B**
Linking trails	**Connectors** public space network elements	Plaza, Pedestrian Plaza, Bridge, Harbor/Marina, Trail, Bike trail, Tree, Canal Lock	**Type C**
Network Interconnected green	**User activity** geolocated data	Concentration of user preferences. Socially relevant urban and natural spaces.	
		States&Municipalities, unclassified venues	**Type D**
Correlation between green spaces and natural systems with urban functions, all interconnected at multi-scale levels.	People use and perception of urban contexts via check-ins in a registered venue. Foursquare 5-level venue category hierarchy indicating the type of place or establisment.		

Table 4
Results. Classification of the retrieved Foursquare dataset subcategories into the proposed Types A, B, and C - GI groupings for Valencia. Identification of selected and discarded subcategories and venues.

Selected subcategories		Number of users	Number of venues	Selected venues according to criteria -section 4.2.2-	Selected venues according to no. of users	Percentage of final selection of venues	Discarded subcategories	No. Users (< 20 users)	No. venues
Type A	Beach	18,027	18	17	10	56%	Campground	10	3
	Park	8119	95	92	46	48%	River	10	1
	Garden	7552	27	27	10	37%	Volcano	9	2
	Botanical Garden	1600	2	2	1	50%	Mountain	7	3
	Lake	177	3	3	1	33%	Island	5	3
	Field	68	8	8	0		Cave	5	1
	Other Great Outdoors (Type A)*	1491	55	53	18	33%			
	No. of selected venues in Type A		**208**	**202**	**86**	**41%**	**No. of discarded venues in Type A**		**16**
Type B	Athletics & Sports	6259	205	205	63	31%	Hot Spring	15	2
	Playground	4594	60	60	22	37%	Palace	13	3
	Pool	1066	41	41	16	39%	Farm	6	1
	Dog Run	383	23	23	2	9%	Ski Area	5	1
	Scenic Lookout	381	22	22	4	18%	Castle	4	3
	Cemetery	148	2	2	1	50%	Lighthouse	3	1
	Sculpture Garden	67	5	5	1	20%	Recreation Center	3	1
	No. of selected venues in Type B		**358**	**358**	**109**	**30%**	**No. of discarded venues in Type B**		**19**
Type C	Plaza	35,449	118	118	72	61%	Bike Trail	2	1
	Pedestrian Plaza	7513	17	17	2	12%			
	Harbor / Marina	6940	14	3	3	21%			
	Bridge	5670	22	22	19	86%			
	Trail	132	9	9	3	33%			
	Other Great Outdoors (Type C)*	2637	86	86	19	22%			
	No. of selected venues in Type C		**266**	**255**	**118**	**44%**	**No. of discarded venues in Type C**		**1**
Total number of users in selected subcategories		**108,273**					Total number of users in discarded subcategories	**108**	
Total number of selected venues from Types A, B and C			**832**	**815**	**313**	**38%**	Total number of discarded venues		**36**

4.2.2. Selection of venues for the city's GI

To ensure an accurate selection of *venues* for the configuration of the GI in the city, further consideration was given to the *venues'* outdoor or indoor character and their public or private management. Indeed, selecting all *venues* is not effective for developing a proper approach to a city's GI definition because only outdoor spaces are considered as elements of the GI —Types A or C— and indoor activities could only be considered in *venues* related to Type B. Thus, perusal of the data and manual labelling, according to each element's specific features, were undertaken to select the *venues* that best fit the definition of each grouping —types A to C—.

The criteria adopted for the selection of *venues* as elements of the GI was as follows:

- Type A - The outdoor + public & private *venues*.
- Type B - All *venues* —outdoor & indoor + public & private—.
- Type C - The outdoor + public *venues*.

Once the *venues* were selected, one last consideration was made. The *venues* were ranked by the value of the total number of registered users and the degree of social significance among them was determined, discarding those under 20 registered users which was arguably not relevant to the local scale of the GI in the case of Valencia.

5. Results

The results are presented in two parts. First, the data grouping and selection of Foursquare subcategories into types A, B, C and D; and, the selection of meaningful Foursquare *venues* which are potential GI elements —see Table 4—. Second, the findings of the first part are compared to what was identified as GI in Valencia's *Revision of the City Urban Plan* approved by the City Council in 2014 (Ayuntamiento de Valencia, 2014).

5.1. Data grouping and selection of subcategories

In total, the *Outdoors & Recreation* main category of the Valencia city dataset included 7.07 % of the total number of *venues* registered in the original dataset. These *venues* were verified to guarantee that there were no duplications.

Table 4 shows the resulting grouping Types and selection of Foursquare subcategories, including a summary of the selection *venue* procedure detailed in section 5.2. The results concerning the classification of subcategories into the three grouping Types —A, B, C—, are presented in two sections: left-hand columns with the selected subcategories (darkest colours); and, right-hand columns with the discarded subcategories (lighter colours).

From an initial number of 1100 *venues,* a total of 1053 were classified into 44 subcategories out of the total amount of 63 general *Outdoors & Recreation* Foursquare sub-classification. Thus, the 95.7 % of *venues* were considered for the analysis.

From a total of 42 Foursquare subcategories, only 19 were relevant according to the number of registered users —seven subcategories in Group A; seven subcategories in Group B; and, five subcategories in Group C—.

During the classification process, the total number of users registered in each subcategory strongly suggested a varying degree of social significance among them. Specifically, in the case of Valencia City dataset, a significant gap was observed between those subcategories with less than 20 registered users than those with more. That is the reason why subcategories with less than 20 registered users were not considered as socially relevant and, therefore, they were discarded for further analysis (Table 4 - lighter colours). This value, set for the case of Valencia, was regarded as a critical indicator of social significance for the coherence of the GI performance and connectivity (see Section 4.2.1). As a result, 23 Foursquare subcategories related to types A —natural elements—, type B —GI attractor facilities—, and type C —GI connectors— were discarded. The remaining subcategories, accounting 832 *venues*, can be considered as socially relevant at city and neighbourhood scale, and thus potential GI elements in relation to user preferences and presence.

5.2. Selection of foursquare venues

After perusal and manual labelling of *venues*, considering their outdoor/indoor character and their public/private management, as well as their social significance, a selection of *venues* was made by applying the criteria described in the research design - Method section.

During this process, it was observed that *venues* classified by users as *Other Great Outdoors* —Type A— included two types of different *venues*: (1) those featured as proper elements of GI, such as areas of great natural value within or in the surroundings of the city; and, (2) a variety of *venues* related to popular urban trails, such as avenues, streets or boulevards, more closely aligned to the description of connectors —Type C—. Therefore, these types of *venues* were individually assigned to either *Other Great Outdoors*-Type A or *Other Great Outdoors*-Type C, respectively.

Table 4 shows the number of *venues* that were assigned to each grouping, as well as the resulting percentage of the selected *venues* for the different subcategories. The selection criteria (Section 4.2.2) excluded *venues* that met one of the following conditions: 1) indoor Type-A *venues* and indoor-private Type-C *venues* in line with the previously described criteria; 2) Indoor and/or private *venues* from Other Great Outdoors subcategory; and, 3) *venues* amounting to less than 20 registered users the value set as non-representative at the local scale in the case of Valencia, as explained in Section 4.2.1.

5.3. Comparison of Foursquare Outdoors and Recreation selected venues to Valencia's GI plan

The comparison between the two maps —first, the visualization of Foursquare's selected *venues* and, second, the current elements configuring the GI network— has been developed at two urban scales: the general area of the city —Fig. 3(a)— corresponds to the scale at which the existing GI plan has been developed; and, a zoom-in on the "Ciutat Vella" historic city-centre—Fig. 3(b)—, which comes under the heritage conservation plan (Ayuntamiento de Valencia, 2019) that provides specific detail related to land use.

Firstly, at the general city scale, most of the elements included in the GI Plan configuration —represented by the shaded green areas and the green and brown lines in Fig. 3(a) and (b) — have been identified by Foursquare users in the category *Outdoors and Recreation*. Some elements are readily identifiable whereas others, especially those that extend across a large area, show a varying concentration and spatial distribution of check-ins. Furthermore, despite only including in this study the *venues* categorized within *Outdoors and Recreation,* which may have excluded elements from the GI Plan that were assigned by users to other categories, Foursquare data was shown to be capable, nonetheless, of identifying the significant GI elements of the city network.

In addition, the representation of Foursquare selected *venues* in different coloured and sized nodes, according to the grouping types and the number of users, respectively, enables a rapid visualization of the user presence in each of the GI elements, thereby complementing the information presented by the GI Plan.

Specifically, according to the different grouping types of Foursquare selected *venues*, the following coincide with the GI elements in the Plan: 46.51 % of Type A natural elements; 5.05 % of Type B facilities; and, 66.10 % of Type C connectors —see Table 5—. Additionally, in comparison to the GI elements of the Plan —at the city scale—, Foursquare data reveals 60.38 % more *venues* that are highly frequented by users and that could be potentially perceived as GI elements. If we observe these results considering the grouping type breakdown, it can be affirmed that Foursquare offers the identification of 53.49 % more of Type A natural elements; 94.49 % more of Type B facilities as hotspots linked to the use of Type A GI elements; and, 33.90 % more of Type C connections for the network.

These findings are further supported by the fact that the selected Foursquare *venues* reveal pockets of activity at neighbourhood scale which are not contemplated by the existing GI Plan. Indeed, despite the mentioned limitations of this LBSN, the results have proven to provide useful information on highly frequented *venues* and, therefore, people preferences for and perception of these spaces —Fig. 3(c)—.

In the case of Valencia GI Plan map not all the green coloured areas (Fig. 3) depict places were the green element is dominant. For example, the main plazas in the historic centre are referent places for the old city urban tissue, and according to the proposed grouping of Foursquare subcategories these are urban public spaces —connectors, Type C— and not natural elements —Type A— (Fig. 3b). Conversely, this same fact has been observed in some main avenues with central green boulevards that have been categorized by users as Park —e.g. Gran vía Fernando el Católico—, or as Other Great Outdoors — e.g. Gran vía Marqués del Turia—. All these observations indicate that Foursquare data provide nuances from the users' perspective that would otherwise be quite difficult to obtain.

6. Discussion

This study deals with the suitability of using data from Foursquare to complement information necessary for the design of GI Plans in consolidated urban areas. The method designed and applied to Valencia City could potentially be regarded as a tool to inform decision-making during the planning process by identifying socially relevant places that should be considered in a GI Plan. The specific advantage and novelty of the method designed relates to distinguishing those spaces that are part of the GI network but have a complementary role —such as activity hotspots, Type B, and connectors, Type C— enabling the selection of user-relevant spaces. This is more likely to result in effective planning strategies that improve the dynamism and social sustainability of the GI. Moreover, the classification and selection process applied to Foursquare *venues* can potentially be reproducible for other urban settings and, also, transposable to similar check-in based LBSNs that are more-commonly used in other countries.

Interesting results emerged when the method was applied to the case study of Valencia. The findings indicated that the interpretation of Foursquare data provided a valuable insight on user perceptions of potential GI elements. Despite the proposed method having been proved useful in consolidated urban areas, where data from LBSN is abundant, four issues arise in relation to using Foursquare for identifying urban GI elements.

Firstly, for the classification process, the subcategories were assigned to their most suitable grouping type —A, B, C or D— by considering the name of the subcategory, which in turn is highly likely to represent the user's perception of city spaces as the user personally assigns a category when registering the *venue*. For example, the subcategories Bridge and Harbour/Marina were considered type C in this case study because of their significant role as itinerary connectors within Valencia's public space network. However, the bridges across the Turia River as well as the Harbour/Marina *venues* could have been

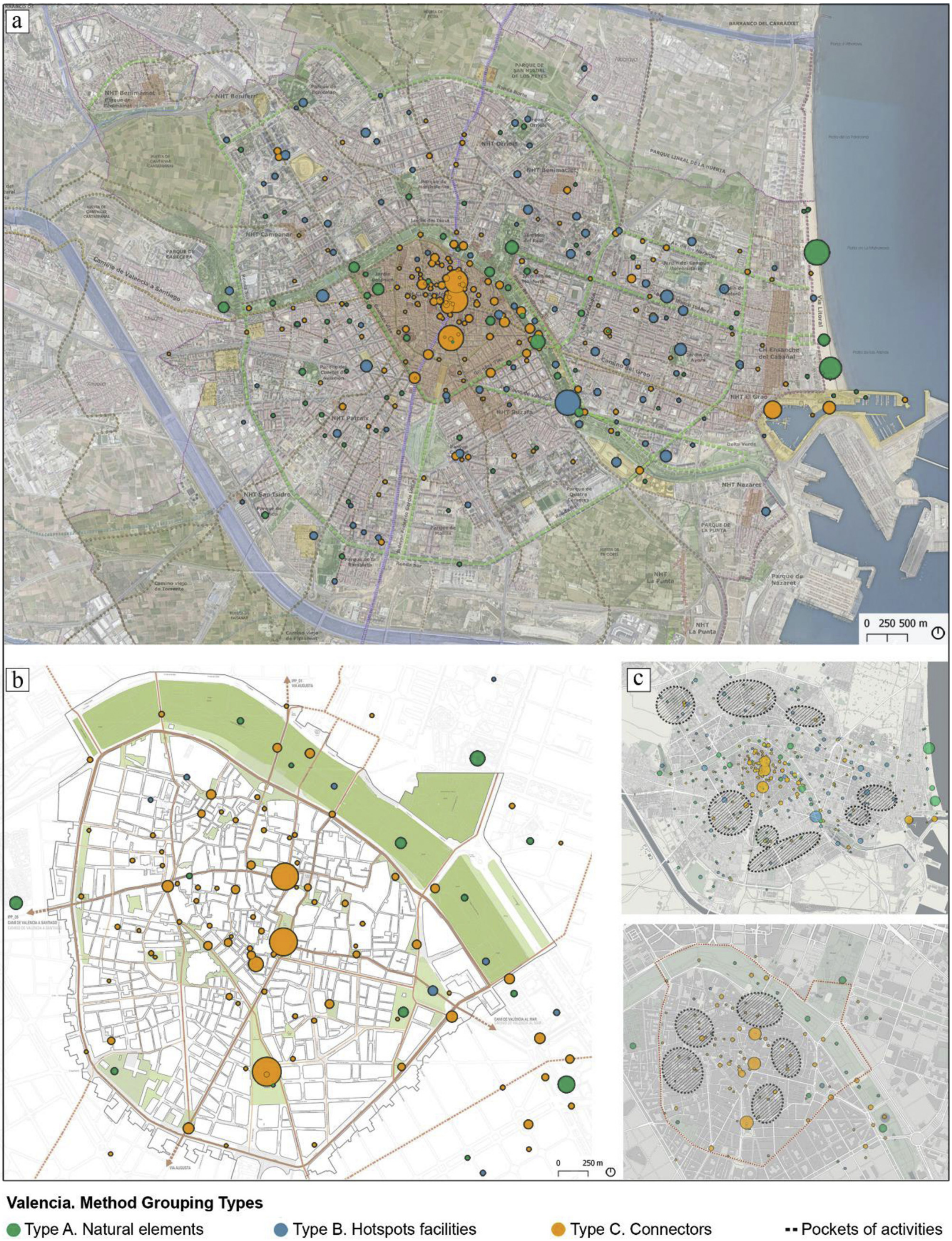

Fig. 3. Overlapping Foursquare user preferences and perception of GI elements onto the GI Plan map of Valencia City. (a) Valencia city scale; (b) historic city-centre scale; (c) Identification of pockets of activities with Foursquare.

Table 5
Breakdown of the comparison between Foursquare selected *venues* and the GI elements included in the Plan.

	Foursquare selected *venues* according to grouping types	Foursquare *venues* identified as elements of the GI Plan		Foursquare additionally identified *venues*	
		Number	%	Number	%
Type A	86	40	46.51 %	46	53.49 %
Type B	109	6	5.05 %	103	94.49 %
Type C	118	78	66.10 %	40	33.90 %
Total Foursquare selected *venues*	**313**	**124**	**39.61%**	**189**	**60.39%**

Table 6
Alternative grouping types considering Foursquare subcategories character in a specific city context.

Foursquare subcategories	Proposed Grouping Types	Alternative Grouping Types
Bridge	C	B
Harbor/Marina	C	A/B
Other Great Outdoors	A	B/C
Pedestrian Plaza	C	B
Plaza	C	B
Pool	B	A
Trail	C	A
Tree	C	A
Waterfront	A	B/C

considered as scenic attractors and assigned to type B grouping. Thus, the manual grouping process of Foursquare subcategories largely depends on the nature of the case study city. Table 6 indicates the most likely possible alternative assignations to different grouping types.

In the case of Valencia, the question of how to classify the subcategories according to the proposed grouping types did not emerge during the classification of subcategories themselves, even though this may have seemed obvious in first instance. However, during the *venue* selection process, it was observed that certain *venues* were assigned to a subcategory that did not strictly fit the researcher expectations. For example, the *venues* of the subcategory Other Great Outdoors were assigned to the different grouping types considering their actual role in the city rather than being guided by initial expectations that surrounded the subcategory name. This approach minimized the distortion of the GI network configuration that could potentially result from the incorrect categorization of *venues*.

Secondly, the method is based on the classification of Foursquare's *Outdoor and Recreation* subcategories; however, other subcategories that do not fall within the *Outdoor and Recreation* main category could potentially have been considered as part of the GI. This is the case of *Outdoor sculpture* and *Street art* sub-subcategories that belong to the *Public Art* subcategory within the *Arts and Entertainment* Foursquare main category.

Thirdly, discarded *venues* after applying the selection criteria corresponded to places that were incorrectly categorized by users. i.e. "Parking Hipercor Campanar" which is the parking lot of a hypermarket, originally and erroneously categorized in the dataset as Park, and thus was discarded. This manual data screening of *venues* is therefore necessary for ensuring the effectiveness of the method, in the sense that non-relevant GI sites or *venues* that may appear popular due to an event or neighbouring attraction are avoided.

The fourth issue has to do with the spatial scope on which the method was applied. Foursquare data is abundant in consolidated urban areas; however, the periphery *venues* that are part of the regional GI scale tend to be ranked by very few users —at least in the case of Valencia—, and therefore were discarded in the process. Clearly these findings evidence the usefulness of Foursquare at an urban scale but also potentially at regional scale because Foursquare also includes relevant natural assets even though they do not register a relevant number of users and check-ins compared to other less important *venues* located in the urban periphery. This is the case of the *Huerta* with very few users —eight registered in the total Huerta area—.

7. Conclusions

The findings indicate that user preferences and perceptions of urban places in consolidated urban areas can be factored in GI plans by using Foursquare data. These data provide an additional layer for the interpretation of the city resulting in a more consolidated approach to planning solutions that include a participatory appraisal. Applying the method designed to the Valencia GI plan, it became apparent that the public spaces network that constitute the GI Plan excluded some key *venues* that were revealed by Foursquare data. Becoming aware of the relevance of these specific *venues* could contribute to the revitalisation of the GI network as these excluded elements are closely aligned to user habits and preferences. Additionally, the identification of Foursquare *venue* concentration nodes across the city can facilitate the design of revitalization and place-making strategies by targeting areas that currently do not seem active. Indeed, if integrated, these areas could potentially increase the resilience of the GI network.

Finally, there are two additional issues to consider: firstly, the GI network design in Spanish cities must be adapted to the existing urban tissue; and, secondly, it should take into account residents' preferences over city spaces, routines or preferred routes. In view of these, Foursquare has proven to be a useful tool to identify users' customs in relation to the use of outdoor public spaces. It can be argued that this information can be, indeed, useful at three planning stages: a) at the city analysis phase, to pinpoint users' relevant outdoor public places as well as other open public spaces that are key for the city's identity as they have a strong social interest; b) at the planning strategy design phase, to include the socially relevant places and/or to introduce attractors to the undervalued —but still relevant— areas; and, c) as a monitoring tool during a post-plan periodic test phase, for keeping track of the social use of GI elements.

All in all, the findings of the study indicate that Foursquare data can be used as a complementary information for analysing and assessing the dynamics of urban spaces with green or natural areas, resulting in an effective tool for GI planning, decision-making and monitoring, sourced by user-generated data. The novel approach of the proposed method is directly linking user presence, preferences, and perception, to GI planning; thereby, improving the social sustainability of GI networks.

Declaration for Conflicting Interest

None.

CRediT authorship contribution statement

Pablo Martí: Supervision, Formal analysis, Writing - original draft, Writing - review & editing, Results validation. **Clara García-Mayor:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Results validation. **Almudena Nolasco-Cirugeda:** Conceptualization, Methodology, Resources, Visualization, Formal analysis, Writing - original draft, Writing - review & editing, Results validation. **Leticia Serrano-Estrada:** Resources, Visualization, Formal analysis, Writing - original draft, Writing - review & editing, Results validation.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104641.

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